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# Tetravalent Chromium ( $\text{Cr}^{4+}$ ) as Laser-Active Ion for Tunable Solid-State Lasers

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## SEMI-ANNUAL PROGRESS REPORT

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(NASA-CR-194528) TETRAVALENT  
CHROMIUM ( $\text{Cr}^{4+}$ ) AS LASER-ACTIVE  
ION FOR TUNABLE SOLID-STATE LASERS  
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## ACCOMPLISHMENTS

During 10/31/92 - 3/31/93 the following summarizes our major accomplishments made under the NASA grant: NAG-1-1346

Self-mode-locked operation of the Cr:forsterite laser was achieved. Synchronous pumping was used to mode locked the forsterite laser resulting in picosecond pulses, which in turn provided the starting mechanism for self-mode-locking. The pulses generated had a FWHM of 105 fs and were tunable between 1230 - 1270 nm.

## ABSTRACTS AND PRESENTATIONS

Several papers were published and presented during the covered period:

1. A. Seas, V. Petričević, and R. R. Alfano, "Generation of Ultrashort Pulses From  $\text{Cr}^{4+}$ :Forsterite", presented at the IEEE/LEOS 1992 Annual Meeting, Boston, Massachusetts, November 16-19, 1992.
2. V. Petričević, A. Seas, and R. R. Alfano, "Current Advances in the Development of Femtosecond Forsterite Lasers", presented at the SPIE's International Simposia on Optoelectronic Packaging and Interconnects, Laser Engineering, and Biomedical Optics, Los Angeles, California, 16-23 January 1993.
3. A. Seas, V. Petričević, and R. R. Alfano, "Femtosecond Pulses Generated From a Synchronously Pumped Chromium-Doped Forsterite Laser", presented at the Topical Meeting on Advanced Solid-State Lasers, New Orleans, Louisiana, February 1-3, 1992.
4. V. Petričević, A. Seas, and R. R. Alfano, "Current advances in the development of femtosecond forsterite lasers", to be published in the Proceedings of SPIE's International Simposia on Optoelectronic Packaging and Interconnects, Laser Engineering, and Biomedical Optics, Los Angeles, California, January 16-23, 1993
5. A. Seas, V. Petričević, and R. R. Alfano, "Femtosecond Pulses Generated From a Synchronously Pumped Chromium-Doped Forsterite Laser", To be published in the

Proceedings at the Topical Meeting on Advanced Solid-State Lasers, New Orleans, Louisiana, February 1-3, 1992.

6. V. Petričević, A. Seas, and R. R. Alfano, "Cr:Mg<sub>2</sub>GeO<sub>4</sub> and Cr:CaMgSiO<sub>4</sub>: New Potential Tunable Solid-State Laser Crystals", To be published in the Proceedings at the Topical Meeting on Advanced Solid-State Lasers, New Orleans, Louisiana, February 1-3, 1992.



Synchronously pumped mode locking was observed when the length of the forsterite laser cavity was matched to the length of the Nd:YAG laser. The output pulses of the synchronously pumped forsterite laser had duration of the order of 200-300 ps. By careful optimization of the cavity by adjusting the position of the laser crystal with respect to the two folding mirrors, the forsterite laser was self mode-locked and the pulsewidth was reduced to 105 fs with a spectral width of the order of 15 nm. In order to confirm that self mode-locking was achieved the cavity length was increased while monitoring the pulsewidth and the pulse train on the oscilloscope. The forsterite laser continued to generate femtosecond pulses even when the length of the cavity was changed by few centimeters. This clearly indicated that the forsterite laser was self mode-locked and that synchronously pumped mode-locking acted as the starting mechanism for self mode-locking. The output power of the forsterite laser when femtosecond pulses were generated was 60 mW.

An intensity autocorrelation trace and the corresponding spectrum of a typical pulse are shown in figure 2 (a) and (b). The pulsewidth shown is 105 fs and the bandwidth is 16 nm. The pulsewidth-bandwidth product  $\Delta\tau_p\Delta\nu = 0.32$ , indicating transform-limited pulses assuming  $\text{sech}^2$  pulses.

Figure 3 shows an oscilloscope photograph of the interferometric autocorrelation trace of the output pulses. Since there is good visibility of the fringes at the wings of the pulse it is evident that the pair of prisms compensated for the chirp introduced by the forsterite crystal. The self mode-locked forsterite laser was tuned using an aperture mounted on a translation stage between prism  $P_2$  and mirror  $M_4$ . Continuous tuning of the laser was achieved between 1240 and 1270 nm limited only by the dielectric coating of the mirrors. The duration of pulses did not vary throughout the whole tuning range.

The stability of the self mode-locked forsterite laser was greatly improved as compared with the previous experiments where the acousto-optic modulator was part of the cavity. The forsterite laser was operating in a self mode-locked mode for up to one hour without significant change in the output pulse characteristics. We believe that the improvement was mainly due to the

absence of the losses and phase distortions due to the mode locker and the birefringent filter.

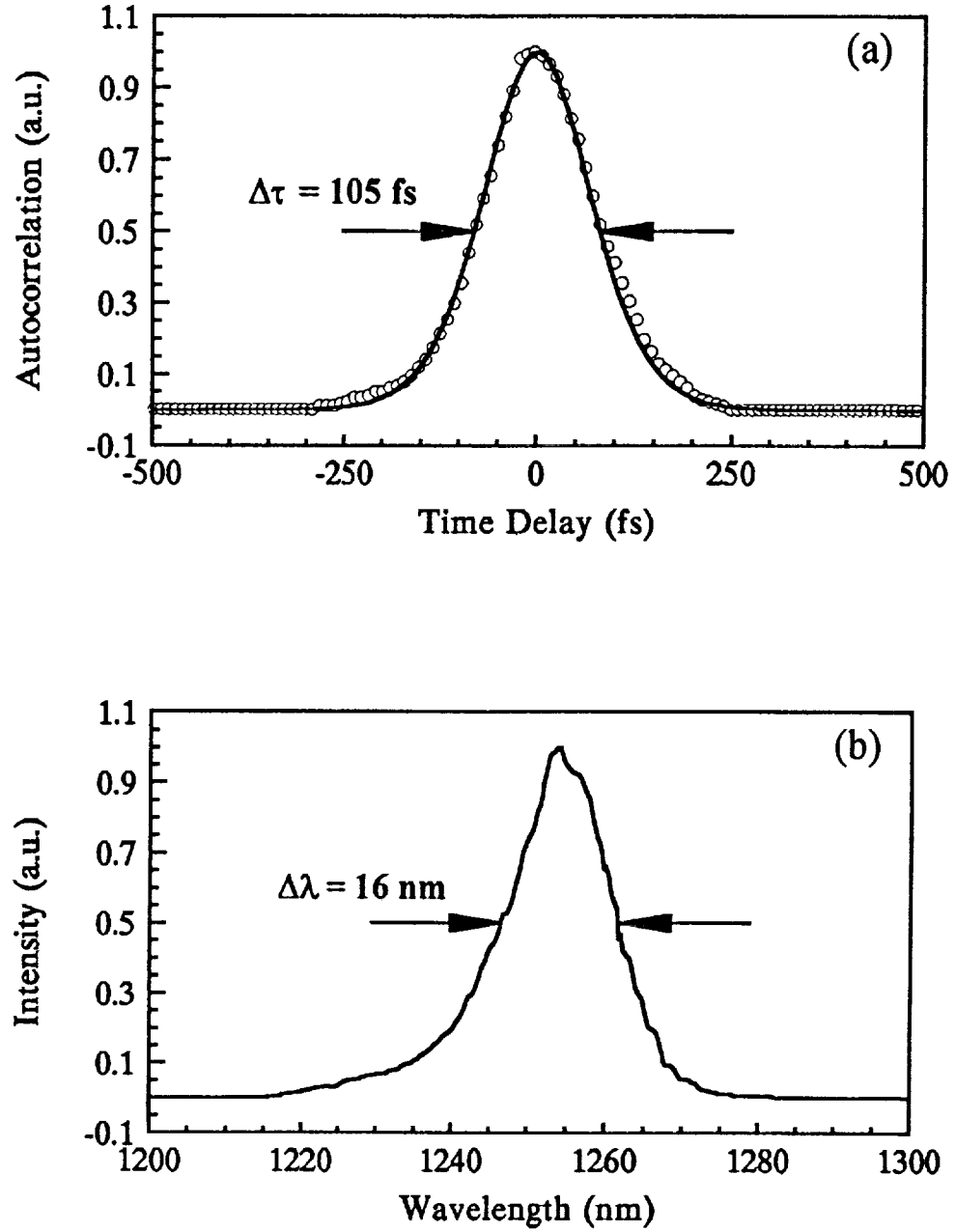


Fig. 2. An autocorrelation trace (a) and spectrum (b) of 105-fs pulses obtained from a z-fold cavity with SF 14 prisms for chirp compensation. Circles represent experimental data and the solid line is the best fit for  $\text{sech}^2$  pulse shape.

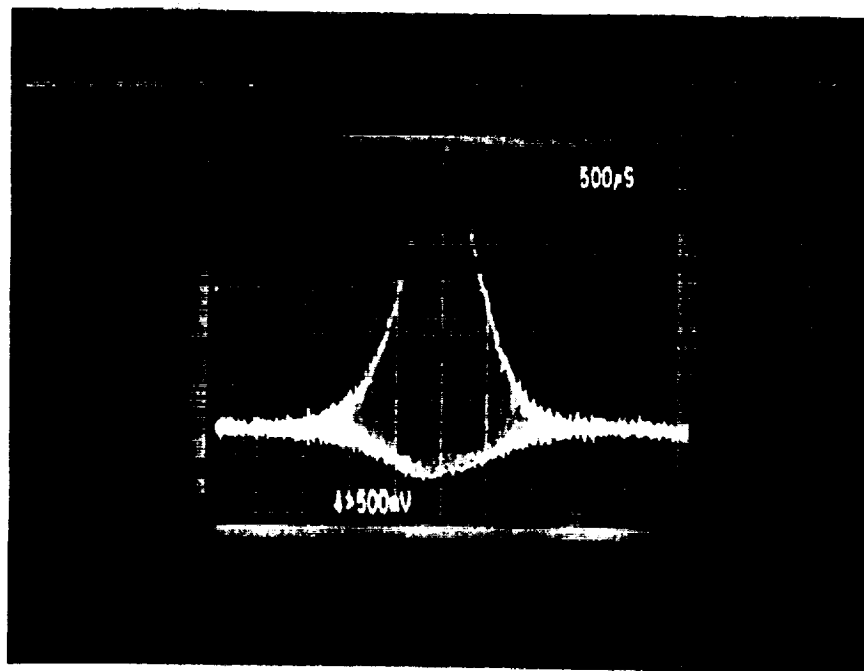


Fig. 3. Interferometric autocorrelation of the output pulses of the forsterite laser.

## REFERENCES

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1. A. Seas, V. Petričević, and R. R. Alfano, "Generation of Sub-100-fs Pulses From a Continuous-Wave Mode-Locked Chromium-Doped Forsterite Laser", *Optics Letters*, Vol. 17, pp. 937 (1992).